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Soil Water and Temperature in Harvested and Nonharvested Pinyon-Juniper Stands

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RESEARCH SUMMARY

Tree harvesting increased soil water content, but the effect diminished over 4 years. The mean increase in soil water content was 2 to 4 percent the first year following harvest and 0 to 3 percent after 4 years. Although tree harvesting released soil water previously used by tree species, other biotic and abiotic demands increased. We speculate postharvest increases in wind and solar energy at the ground surface and increased understory transpiration in part explain the decline in soil water content differences between harvested and nonharvested plots over time.

Understory cover increased three to six times following tree harvest on north and west aspects. Understory apparently used soil moisture made available by tree harvesting.

Duff soil microsites had consistently greater soil water than transition or interspace microsites. The duff microsite accumulated soil moisture immediately after tree removal similar to that reported for debris-in-place treatments following chaining. The duff microsite serves as both a mineral nutrient pool and a soil water reservoir. Management should consider the impact of tree harvesting and slash disposal on the nutrient-rich and soil water-rich duff microsite. Destruction of duff during tree removal and burning of slash should not be encouraged.

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INTRODUCTION

The pinyon-juniper woodland of the Great Basin has a mediterranean climate. Soil moisture is depleted in summer and recharged in winter (Gifford and Shaw 1973). Gifford's (1975) water budget for pinyon-juniper woodlands shows a majority of annual precipitation is lost by evapotranspiration and interception. Little runoff or deep percolation occurs.

In environments where water is limiting, natural selection favors those species that compete for soil water and use it effectively. Woodbury (1947) and Plummer (1958) have previously noted the ubiquitous root stems of pinyon (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) in woodland stands. Root systems of singleleaf pinyon (*Pinus monophylla*) and western juniper (*Juniper occidentalis*) are composed of surface feeder roots under the tree crown and deeper laterals that occupy the interspace areas between trees (Young and others 1984; Everett 1984). Jeppesen (1977) found western juniper withdrew much of the winter accumulation of soil moisture before associated understory species broke dormancy. Emmerson (1932) found that soil moisture withdrawal by pinyon roots closely followed evaporative demand.

Canopy interception reduces the amount of precipitation reaching the soil surface (Collings 1966). Depth of soil wetting was found to be inversely related to crown density above the sample point (Gifford 1970). Stemflow channels precipitation to soils adjacent the tree stem, but the amount is only a small fraction (0.23 percent) of that intercepted by the tree crown (Young and others 1984).

Removal of trees can increase soil moisture. Gifford and Shaw (1973) studied soil moisture trends in undisturbed pinyon-juniper stands and stands subjected to chaining followed by windrowing and burning of debris. Undisturbed woodlands were found to have the least soil moisture and debris-in-place treatments to have the greatest moisture accumulation. Skau (1964) suggested that tree harvesting of pinyon-juniper stands may considerably increase the water available for forage production. Soil moisture was found to increase over undisturbed stands following felling of alligator juniper (*Juniperus deppena*) and Utah juniper (1.1 and 2.5 percent increase, respectively). The ninefold increase in understory cover on clearcut plots was believed to be the major cause for the small postharvest increase in soil moisture. Everett (1984) found understory cover and yield response to tree harvest was greater on tree-associated soil microsites than in the interspace between trees. This may be the result of increased soil nutrient availability (Everett 1984), improved soil moisture status, or both.

In this study we measured soil matric potentials and percentage soil moisture in tree-harvested and nonharvested pinyon-juniper stands. Soil water measurements were taken in each of the three major soil microsites (duff, transition, and interspace) in each plot. Measurements were taken in what we believed to be the major rooting zone of herbaceous species on the site (Everett 1984). We asked three major questions of our data: (1) Was there a difference in soil water between tree-harvested and nonharvested plots? (2) Was there a difference in soil water among soil microsites? (3) Did soil water vary between 15- and 30-cm soil depths? Finding differences in soil water among tree microsites on harvested plots would suggest the need for cultural prescriptions to protect these microsites during tree harvest.

METHODS

In 1979 three 0.1-ha plots were clearcut of singleleaf pinyon and Utah juniper. Plots occurred on north, west, and south aspects within 2 km of each other on the Shoshone Mountain range of central Nevada. Areas adjacent the tree harvest plots were selected as controls and the three pairs of plots fenced to exclude livestock.

The understory was comprised of perennial grasses Sandberg bluegrass (*Poa sandbergii*), Idaho fescue (*Festuca idahoensis*), squirreltail (*Sitanion hystrix*), and junegrass (*Koeleria cristata*). The ratio of tree cover to grass cover was 28/3, 61/2, and 54/1 percent on north, west, and south aspects, respectively. Pinyon cover exceeded juniper cover in all instances. Elevation at the site was 2 310 m. Precipitation was estimated at 320 mm, 300 mm, 330 mm, and 439 mm for the 4-year

study (1980 to 1983). Estimates were the mean value from the two closest weather stations in the same vegetative type 10 km and 70 km distant.

Soils on the site were classified as clayey-skeletal, mixed, frigid, lithic Xerollic Haplargids (USDA 1975). Soils occurred on 14 to 18 percent slopes on north-south ridges. The soil surface was a mosaic of soil microsites, duff, transition, and interspace. Duff microsites occurred under the tree crowns and were defined as those microsites having greater than 0.5 cm depth of continuous needle cover. Transition microsites had discontinuous needle cover less than 0.5 cm deep in a ring at the tree crown perimeter. Interspace microsites had negligible needle cover and occurred between trees.

Soil Water and Temperature Measurements

Matric water potential was recorded on soil microsites in tree-harvested and nonharvested plots. In each plot the soil microsites, duff, transition, and interspace adjacent to two randomly selected trees were chosen for sampling. Gypsum soil moisture blocks (Delmhorst GB-1 cylindrical gypsum blocks) were pressed into the sides of a narrow soil pit at 15- and 30-cm depths. A copper-constantan thermister was placed with each 15-cm deep block to measure soil temperature.

Moisture blocks and thermisters were put in the ground at the time of tree harvest in June 1979 and read from 1980 to 1983. Gypsum blocks remain in good condition for 3 to 5 years under field conditions (Roundy and others 1983). Measurements were taken prior to loss of snow cover (April-May) until late summer (September) at 2- to 4-week intervals. A total of 1,116 soil water and 553 temperature readings were taken during the study. To facilitate comparisons between sample dates, most measurements were taken from 6 to 8 a.m.

Thermister readings in microvolts were converted to temperature readings (°F) using water bath calibration curves. Water content measurements in resistance (ohms) were converted to bars of soil matric potential using the equation provided by Roundy and others (1983): bars = $([4.253 * 10^{-4} \text{ ohms}] + 0.2)$. Because total soluble salts were low (0.1 to 0.4 S dm^{-1} [1 bar]: Everett 1984) matric potential closely approximates total soil water potential.

The effective measurement range of gypsum blocks is 0 to -15 bars; a range exceeded under a semiarid climate. To expand the range of our soil measurements we calibrated moisture block resistance readings (ohms) to percentage soil moisture in laboratory tests. Moisture blocks were placed in glass jars (27 replicates) filled with soils from the site. Soils were wetted, the jars sealed and heated at 100 °C for 24 h to vaporize the water, and then allowed to cool. Moisture block resistance and percent soil moisture were recorded after a 24-h equilibration period. Lids were then removed, a portion of the soil water driven off by heating, jars resealed, and the procedure repeated. The derived exponential calibration curve (soil moisture = $83.796\ e^{-0.434 \text{ ohms}}$) had a coefficient of determination (r^2) of 0.85. The curve is asymptotic above saturation and ineffective in measuring increased soil water content.

Understory cover was recorded on the harvested and nonharvested plots from 1979 to 1983. Each plot had five permanent transects 20 m in length at 5-m intervals across slope. A 50-cm square sampling frame was laid down every 1 m, and understory crown cover was estimated by Daubenmire's canopy coverage method (1959).

Analysis

Soil moisture readings for a given year were analyzed by t-tests of differences. The experimental unit was the mean of two values for a given soil depth or the mean of four values for a given microsite on a given date. There were six to 11 replicates to test for differences in soil moisture between harvested and nonharvested plots and among soil microsites in a given year. There were four replicates over time (1980 to 1983) to test for differences among aspects. Each of the four replicates represented the mean of 30 to 60 observations. The reader is cautioned that, because aspect plots were not replicated over space, results may not apply to the population from which sites were drawn.

RESULTS AND DISCUSSION

Both soil water content and soil temperature increased following tree harvesting. The increase was short lived as understory cover increased rapidly. Soil moisture content of soil microsites was uniform on nonharvested plots, but variable on harvested plots.

Matric Water Potential

Soil water content was greater on tree-harvested than nonharvested plots, but the difference declined over 4 years (table 1). Soil moisture was generally 2 to 5 percent greater on harvested plots but varied from 0 to 12 percent among sites and years. Results were somewhat higher than Skau's (1964) report of a 1 to 2 percent increase in soil water following tree harvest. But values were within the 0 to 15 percent increase in soil moisture reported by Gifford (1975).

Contrary to our expectations, we found soil water to be significantly ($p = 0.1$) greater on the south than north harvest plot in 1980 and 1981. The trend reversed itself in 1982 and 1983. Soil water patterns varied from year to year (fig. 1). Soil water rapidly declined with the summer drought in early June and increased following precipitation in late August or September. Soil water content was consistently lower on nonharvested plots than harvested plots throughout the growing season. Differences in soil water between harvested and nonharvested plots were least in the fourth year of study.

Matric water potentials were near zero in early spring under snow cover but rapidly exceeded -15 bars. The mean date for soil water to exceed -15 bars was June 29 on harvested plots and June 19 on nonharvested plots. Matric potentials less than -15 bars occurred 19 days later on harvested than nonharvested plots the first year following tree harvest. This relationship varied among years, and by the fourth year matric potentials less than -15 bars occurred 5 days earlier on harvested plots.

Soil water content was greater at the 30 cm than at the 15 cm depth, but not significantly so. Mean soil

Table 1.—Percentage soil moisture for harvested and nonharvested plots on south, west, and north aspects (means over all microsites, depths, and sample dates)

Aspect	1980 H	1980 N[1]	1981 H	1981 N	1982 H	1982 N	1983 H	1983 N
	Percent soil moisture							
South	22.6*[2]	17.8	22.8**	9.5	18.8**	13.2	18.6[ns]	18.6
West	20.2[ns]	18.4	14.7*	10.4	17.1[ns]	17.1	20.5[ns]	18.9
North	19.9[ns]	15.7	11.0[ns]	9.6	19.1[ns]	16.7	21.3[ns]	18.2

[1]H = harvested plot, N = nonharvested plot.
[2]*, ** = significant differences (p = 0.1, 0.05) between harvested and nonharvested plot values.
ns = nonsignificant difference.

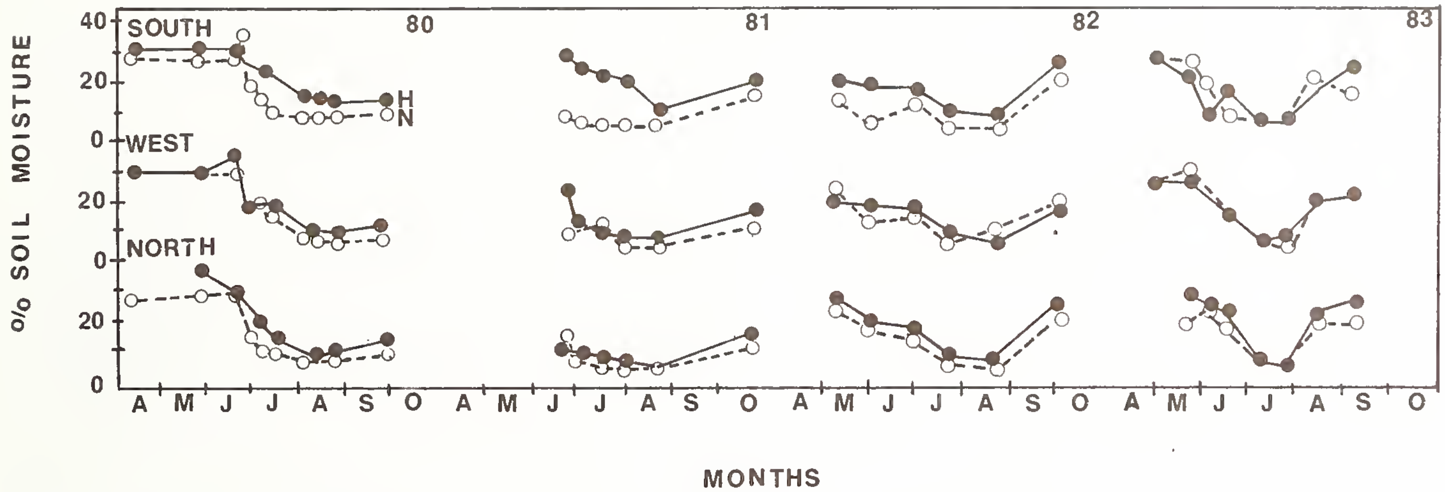

Figure 1.—Soil water content in tree-harvested (H) and nonharvested (N) plots on south, west, and north aspects in 1980, 1981, 1982, and 1983.

Table 2.—Mean percentage soil moisture on harvested and nonharvested plots by year and soil microsites

Type of plot	1980 D	1980 T	1980 I[1]	1981 D	1981 T	1981 I	1982 D	1982 T	1982 I	1983 D	1983 T	1983 I
	Percent soil moisture											
	South											
Harvest	27.5[a2]	18.9[b]	20.5[ab]	25.6[a]	19.5[b]	21.7[ab]	18.8[a]	17.9[a]	18.2[a]	20.7[a]	18.1[a]	20.8[a]
Nonharvest	17.0[a]	17.8[a]	14.5[a]	9.5[a]	10.2[a]	9.5[a]	12.0[a]	14.7[a]	11.6[a]	19.0[a]	19.0[a]	18.9[a]
	West											
Harvest	24.1[a]	15.2[b]	20.4[ab]	17.9[a]	9.4[b]	13.6[b]	17.1[a]	15.8[a]	17.8[a]	19.5[a]	19.7[a]	19.5[a]
Nonharvest	18.0[a]	18.8[a]	18.0[a]	7.7[a]	10.3[a]	8.4[a]	14.0[b]	20.3[a]	16.7[b]	20.9[a]	21.4[a]	20.4[a]
	East											
Harvest	25.3[a]	14.5[b]	14.0[b]	15.2[a]	9.3[b]	8.9[b]	21.1[a]	18.0[a]	18.2[a]	22.5[a]	20.7[a]	21.0[a]
Nonharvest	19.9[a]	14.3[a]	15.5[a]	10.1[a]	7.1[a]	10.5[a]	16.7[a]	15.6[a]	17.8[a]	19.1[a]	17.3[a]	18.2[a]

[1]D = duff microsite, T = transition microsite, and I = interspace microsite.
[2]Microsites on the same plot (row) with different superscripts are significantly (p = 0.05) different.

water (all years and aspects combined) on harvested plots was 17.7 percent at 15 cm and 19.6 percent at 30 cm. Mean soil water on nonharvested plots was 14.9 percent at 15 cm and 15.3 percent at 30 cm. Relatively more moisture was available in subsurface horizons for deep-rooted species. Lateral roots from juniper or pinyon (Emmerson 1932; Young and others 1984; Everett 1984) occur in subsurface horizons. The long-term capability of the trees to capture subsurface soil moisture and associated nutrients is indicated by nutrient accumulation under the tree crowns (Barth 1980; Everett 1984).

Duff soil microsites had greater soil water content than interspace or transition microsites on harvested plots (table 2). The duff microsite accumulated soil moisture much like the debris-in-place microsite created by

chaining and windrowing (Gifford 1982). Differences among soil microsites on harvested plots declined over years. There were no significant differences in soil water content among microsites on nonharvested plots.

Soil Temperature

Mean soil temperature at the 15-cm depth was always greater on harvested than nonharvested plots during the growing season (table 3). The obvious loss of tree shade and recorded higher soil temperatures in harvested plots suggest increased solar radiation to the soil surface. Gifford (1973) reported triple the amount of wind on sites where pinyon and juniper trees had been removed. Evaporative demand on tree-harvested sites would be intensified by both solar and wind increases. Differences in soil water between harvested and nonharvested treatments would be diminished.

Table 3.—Soil temperature at 15-cm depth on harvested and nonharvested plots (mean of all soil microsites and years)

South		West		North	
H	N[1]	H	N	H	N
°C					
15.8[a2]	13.1[b]	13.3[a]	12.3[b]	13.6[a]	11.4[b]

[1]H = harvested plots, N = nonharvested plots.
[2]Harvested and nonharvested plot values for the same aspect that have different superscripts are significantly (p = 0.05) different.

We found no difference in soil temperature among soil microsites in harvested plots, but surface temperatures increased from the duff to the interspace in nonharvested plots (table 4). Grasses in interspace microsites on nonharvested plots are faced with both low soil water and high soil temperature regimes. Reduced understory cover in the interspace microsites has been previously reported (Everett 1984).

Table 4.—Soil temperature at 15-cm depth for soil microsites on harvested and nonharvested plots (mean for all aspects and years combined)

Harvest			Nonharvest		
D	T	I	D	T	I[1]
°C					
11.0[a2]	12.3[a]	13.3[a]	13.8[c]	14.3[b]	14.0[a]

[1]D = duff, T = transition, and I = interspace microsites.
[2]Microsite values with different superscripts in harvested or nonharvested plots are significantly (p = 0.05) different.

Understory Cover

Grass cover significantly ($p = 0.05$) increased from 5 to 15 percent on the north aspect and from 2 to 13 percent on the west aspect following tree harvest. Cover on the south aspect was initially low and did not exceed 4 percent after 4 years. Soil water was greatest on the south slope. Perhaps reduced transpiration on this sparsely vegetated site caused this anomaly. Soil water differences between harvested and nonharvested plots were least on north and west aspects where the increase in understory cover was greatest. We observed that duff microsites with a deep needle cover inhibited understory establishment.

CONCLUSIONS

Tree harvesting increases soil water, but only temporarily. Transpiration from released understory and evaporation from the soil surface are speculated to rapidly reduce initial postharvest soil water levels. Soil water is relatively greater under the duff surrounding cut stems. These microsites are also nutrient-rich and provide a favorable environment for understory growth at their periphery. Where understory is associated with the duff microsite, these microsites should be protected from destruction during tree harvesting and slash disposal. Because duff tends to inhibit establishment of understory species, this recommendation is not valid when tree harvest sites are to be seeded.

REFERENCES

Barth, R. C. Influence of pinyon pine trees on soil chemical and physical properties. Soil Science Society of America Journal. 44: 112-114; 1980.

Collings, M. R. Throughfall for summer thunderstorms in a juniper and pinyon woodland, Cibecue Ridge, Arizona. Professional Paper 485-B. Washington, DC: U.S. Department of the Interior, U.S. Geological Survey; 1966. 13 p.

Daubenmire, R. Canopy coverage method of vegetation analysis. Northwest Science. 33: 43-64; 1959.

Emmerson, F. W. The tension zone between the gramma grass and pinyon juniper associations in northeastern New Mexico. Ecology. 13: 347-358; 1932.

Everett, R. L. Understory response to tree harvesting in pinyon-juniper woodlands of the Great Basin. Corvallis, OR: Oregon State University; 1984. 174 p. Ph.D. dissertation.

Gifford, G. F. Some water movement patterns over and through pinyon-juniper litter. Journal of Range Management. 23: 365-366; 1970.

Gifford, G. F. Influence of chaining pinyon-juniper on net radiation, solar radiation and wind. Journal of Range Management. 26: 130-133; 1973.

Gifford, G. F.; Shaw, C. B. Soil moisture patterns on two chained pinyon-juniper sites in Utah. Journal of Range Management. 26: 436-443; 1973.

Gifford, G. F. Approximate annual water budgets of two chained pinyon-juniper sites. Journal of Range Management. 28: 74-75; 1975.

Gifford, G. F. Impact of burning and grazing on soil water patterns in the pinyon-juniper type. Journal of Range Management. 35: 697-699; 1982.

Jeppesen, D. J. Competitive moisture consumption by the western juniper (*Juniperus occidentalis*). In: Proceedings, western juniper ecology and management workshop; 1977 January; Bend, OR. General Technical Report PNW-74. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1977: 83-90.

Plummer, A. P. Restoration of juniper-pinyon ranges in Utah. In: Proceedings, Society of American Foresters Meeting; 1958 September-October; Salt Lake City, UT. Washington, DC: Society of American Foresters; 1958: 207-211.

Roundy, B. A.; Young, J. A.; Cluff, G. J.; Evans, R. A. Measurement of soil water on rangelands. Agriculture Research Results ARR-W-31. Washington, DC: U.S. Department of Agriculture, Agriculture Research Service; 1983. 27 p.

Skau, C. M. Soil water storage under natural and cleared stands of alligator and Utah juniper in northern Arizona. Research Note RM-24. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1964. 3 p.

U.S. Department of Agriculture, Soil Conservation Service. Soil taxonomy. Agriculture Handbook 436. Washington, DC; 1975. 754 p.

Woodbury, A. M. Distribution of pigmy conifers in Utah and northeastern Arizona. Ecology. 28: 113-126; 1947.

Young, J. A.; Evans, R. A.; Easi, D. A. Stemflow on western juniper (*Juniperus occidentalis*) trees. Weed Science. 32: 320-327; 1984.

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Soil water and temperature initially increased following tree removal. The duff soil microsite accumulated soil moisture and the transition microsite at the edge of the duff became depleted. The south aspect had the greatest increase in soil moisture and the least understory cover. Differences in soil moisture between harvest treatments declined over the 4-year study as understory cover increased.

KEYWORDS: soil water, pinyon, juniper, Great Basin, tree harvest

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